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WO 98/04006 A1 US 4816183 A US 4625071 A  
Pat.Abs.of JP,Vol.17, No.22 (E-1307), 14/7/93, page 94  
and JP4 -249375 (SHARP)

(58) Field of Search

UK CL (Edition Q) H1K KEBCA KEBCS KEBCX KEBX  
KECA  
INT CL<sup>6</sup> H01L  
ON LINE,W.P.I.,EPODOC,JAPIO

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(54) Abstract Title

A solar cell comprising clusters in the active region

(57) The cell comprises an active region in which charge carriers are generated by incident photons and clusters of atoms or molecules in the active region cause the cell to exhibit a peak in the absorption spectrum. The cell may be an organic Schottky contact cell with silver clusters in the active layer. The clusters give rise to an absorption peak in a wavelength region where a conventional cell without clusters exhibits an absorption minimum.

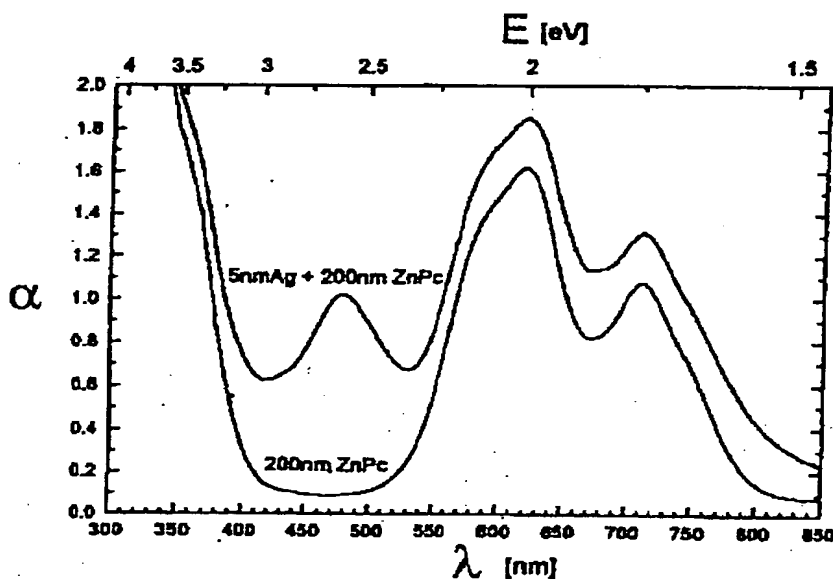


Figure 1

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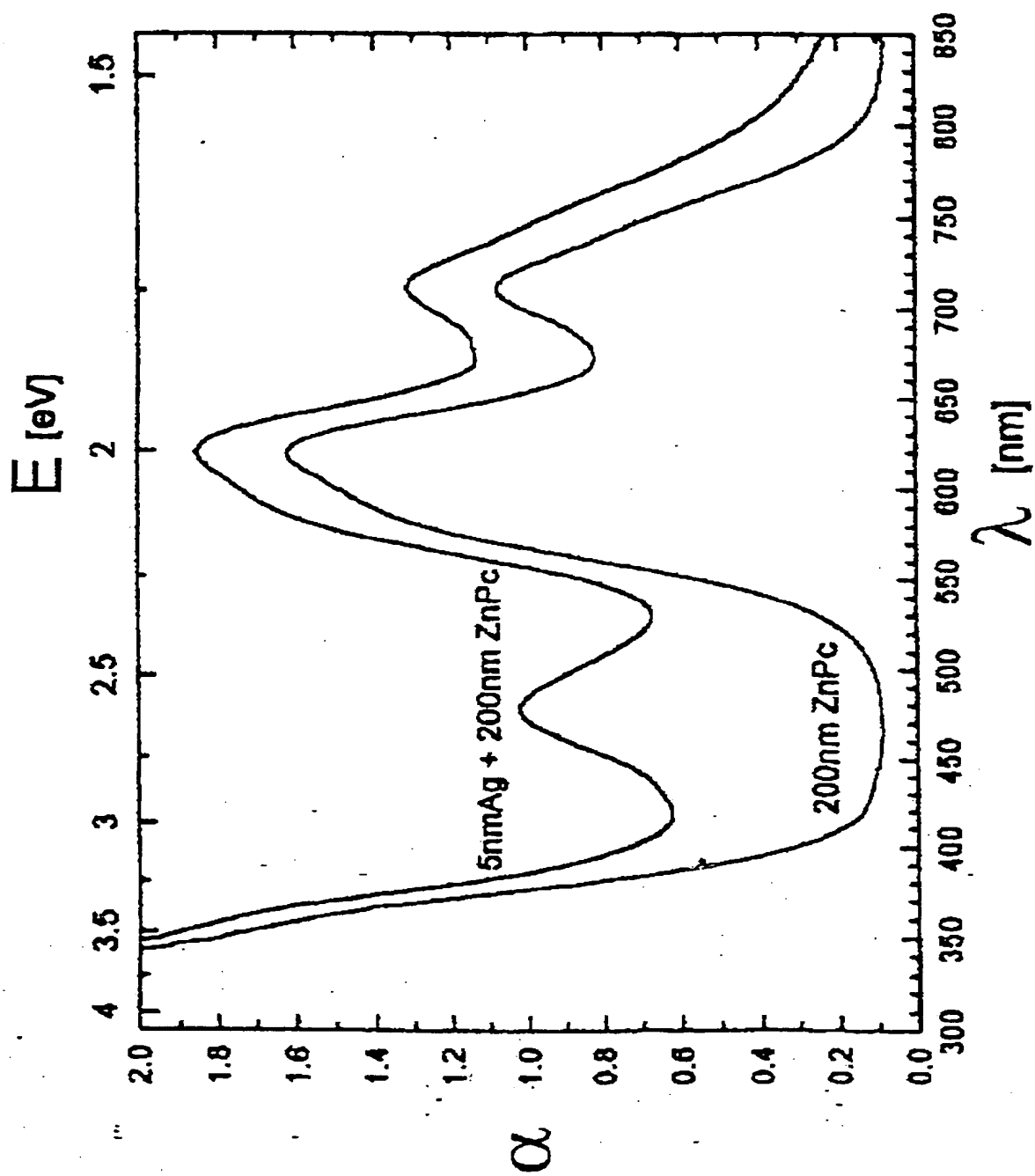


Figure 1

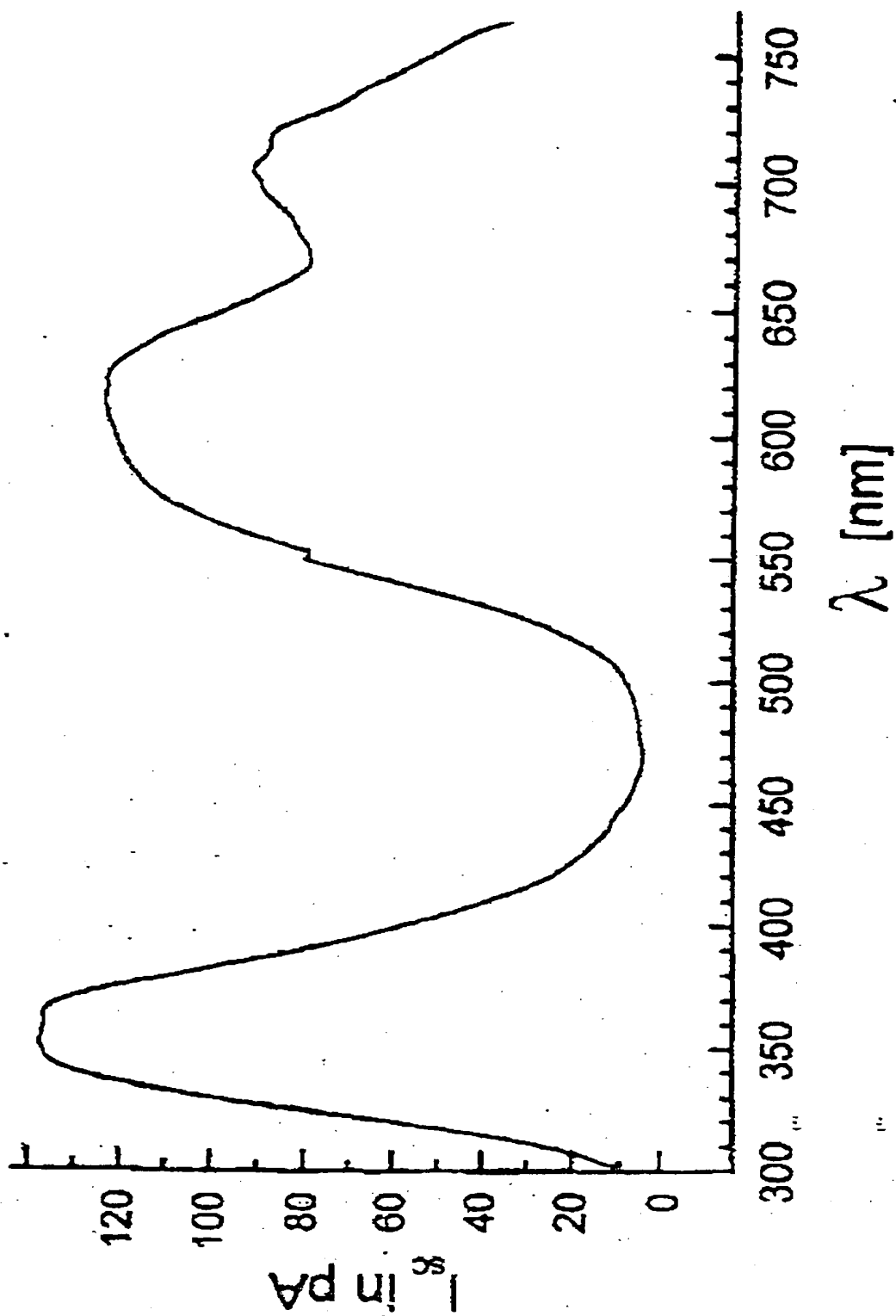


Figure 2

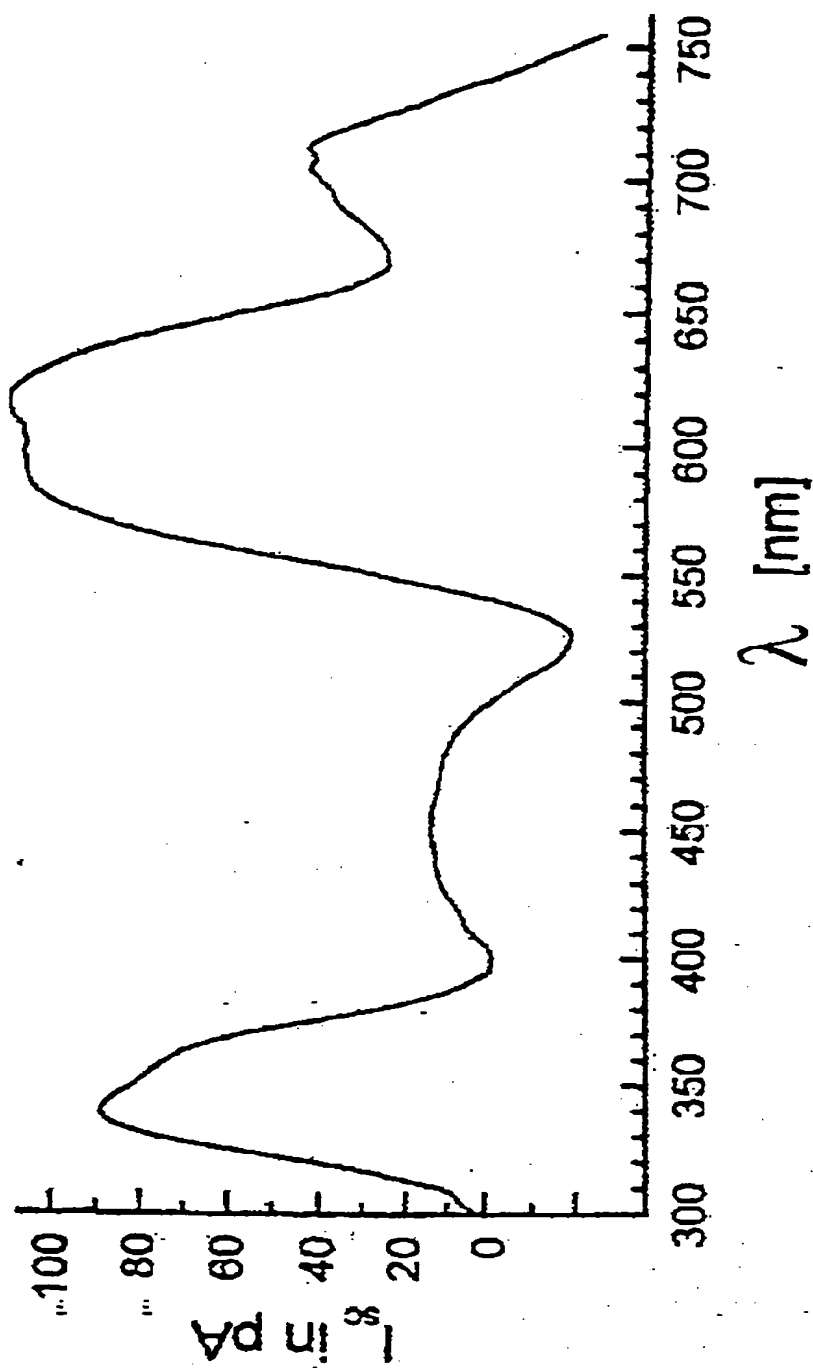


Figure 3

A solar cell comprising clusters in the active region

This invention relates to a solar cell having the features of the precharacterising clause of claim 1. In a solar  
5 cell, an electric current is generated by the absorption of electromagnetic radiation. The current which is generated is termed a photocurrent.

A solar cell such as this, in which photons are converted  
10 into an electric current in a dye, is known from the document DE 196 40 065 A1.

In the active zone (active region) of a solar cell, incident photons result in charge separation. A charge  
15 carrier pair is formed as a result of this charge separation. If one charge carrier of the charge carrier pair, for example an electron, is conducted out of the active zone, an electric current flows. The separate outward conduction of charge carriers of a charge carrier  
20 pair is achieved by the provision of a suitable electric field. A suitable electric field prevails in solar cell, for example, as a result of providing a p-n contact with a depletion zone between the n-type and the p-type conductors. This depletion zone then forms the active zone.

25 The efficiency of the absorption of incident photons and of the conversion thereof into charge carrier pairs depends on the wavelength the photons. Depending on the wavelength, the efficiency exhibits local minima, local maxima or  
30 edges.

It is known from the document by M. Quinten, O. Stenzel, A. Stendal, C. Borczyskowski (J. Opt. 28 (1997) 249-251) that clusters can be introduced into regions outside the active

zone of a solar cell and that the efficiency can thus be increased. However, this increase only occurs at wavelengths at which there is a high efficiency anyway.

- 5 The object of the present invention is to provide a solar cell having a good efficiency.

This object is achieved by a device which has the features of the main claim. Advantageous forms of construction  
10 follow from the dependent claims.

The solar cell according to the claims has an active region in which charge carrier pairs are produced by incident photons. A charge carrier pair consists of a positive and a  
15 negative charge carrier. Means are provided for conducting the charge carriers out of the active region so that an electric current flows. Negative charge carriers such as electrons are then conducted out of the active region separately from positive charge carriers, or vice versa.  
20 Clusters are situated within the active region.

Suitable applied electric fields are examples of means which result in the conduction of charge carriers out of the active region in order to generate an electric current.  
25 Suitable applied electric fields for a solar cell can be provided, for example, by a p-n contact with a depletion zone between the n-type and p-type conductors, or by a Schottky contact, or by molecular arrangements comprising suitably located energy states or Fermi levels.

30

In combination with the active region, the purpose of the means for conducting charge carriers out of the active region is to provide an electrical voltage.

Clusters in the sense of the claims should be understood to be a group of three or more atoms or molecules, each of which is chemically linked to at least two other atoms or molecules of this group. Said linkage can consist of  
5 metallic, ionic, covalent or van der Waals-type bonds. The clusters exhibit an absorption peak. An absorption peak exists if the photon absorption exhibits a local maximum which depends on wavelength. As distinct from the clusters according to the claims, a metal layer of macroscopic size  
10 does not exhibit a local absorption peak.

The clusters according to the claims consist, for example, of 5000 gold atoms or of 3000 gallium arsenide molecules.

15 In the wavelength region of the absorption peak, clusters in the active region of a solar cell give rise to additional photon absorption, which, in contrast to an extensive metal layer of macroscopic size, results in resonance. Additional charge carrier pairs are thereby  
20 produced in the active zone. The efficiency of the solar cell is thus increased.

An advantageous form of the solar cell according to claim 2 comprises clusters which are smaller than 100  $\mu\text{m}$ , and which  
25 in particular are smaller than 10  $\mu\text{m}$ . Clusters of this order of magnitude result in a pronounced absorption peak and thus result in improved resonance. The consequence is a further increase in efficiency of the solar cell.

30 The solar cell according to claim 3 advantageously contains clusters which consist of at least 100 atoms, and which consist in particular of at least 1000 atoms. A typical cluster contains 10,000 atoms, for example.

If the number of atoms in a cluster is too low, the absorption peak is very narrow. This disadvantageously results in absorption over a very narrow wavelength range. The clusters should therefore consist of at least 100  
5 atoms, preferably of at least 1000 atoms, in order to obtain an absorption peak over a broad wavelength range.

An advantageous solar cell according to claim 4 contains clusters in the active region, the absorption peak of which  
10 falls within the wavelength range in which the efficiency of the solar cell without clusters exhibits a local minimum or which exhibits an increase in an absorption edge.

One example of a solar cell according to claim 4 is a  
15 Schottky contact solar cell comprising silver clusters in the active region which are a few nanometres in size. This solar cell consists of ITO (indium/tin oxide)-coated glass comprising a zinc phthalocyanin layer which is deposited by vacuum evaporation. Without clusters, this exhibits a local  
20 absorption minimum and thus exhibits a local photocurrent minimum within the range from 410 - 520 nm. The silver clusters exhibit a local absorption peak in the  
- aforementioned range. Therefore, light in the wavelength region of around 470 nm is also converted at high  
25 efficiency into a photocurrent. The consequence is a local maximum of the photocurrent in the region around 450 nm.

A solar cell which contains cadmium sulphide as a semiconductor constitutes a further example. In the absence  
30 of the clusters according to the invention, there is an absorption edge which falls off steeply at 520 nm. Gallium arsenide clusters which are introduced into the active region give rise to an additional electric current at wavelengths around 600 nm. This wavelength region could not

be utilised hitherto. The efficiency is thus further increased.

5 A solar cell according to claim 5 advantageously comprises clusters in the active region, the absorption peak of which fall within in the wavelength range of visible light. These clusters may consist of silver or gold.

10 In one example, the solar cell comprises a glass which is coated with ITO (indium/tin oxide) and a zinc phthalocyanin layer which is deposited by vacuum evaporation. This exhibits an absorption minimum with in the wavelength range from 410 - 520 nm. By the provision according to the invention of silver clusters of nanometre size, photons  
15 from the visible wavelength range and thus from the high-energy wavelength range are more intensively converted into a photocurrent in the region around 450 nm. The efficiency is thus improved further.

20 It has been shown that the efficiency can be improved by at least 10 % to 15 % overall.

The invention is explained in greater detail below with reference to an example, wherein the accompanying Figures  
25 are as follows:

Figure 1 shows the photon absorption spectrum as a function of wavelength for a solar cell comprising silver clusters in the active region  
30 (5 nm Ag + 200 nm ZnPc), compared with a conventional solar cell according to the prior art (200 nm ZnPc);

Figure 2: shows the photocurrent spectrum as a function of

wavelength for a conventional solar cell; and

Figure 3: shows the photocurrent spectrum as a function of wavelength for a solar cell comprising silver clusters in the active region.

Organic Schottky contact solar cells were used. Each cell comprised glass which was coated with ITO (indium/tin oxide). The coating was in contact with a vacuum-evaporated layer of zinc phthalocyanin about 200 nm thick. The active layer contained silver clusters of size about 5 nm, which were produced by vacuum evaporation on a silver layer about 1.3 nm thick, which was held at 180 degrees Celsius for 10 minutes.

Figure 1 illustrates the dependency of photon absorption  $\alpha$  on wavelength  $\lambda$  or on photon energy  $E$  for a solar cell according to the invention (upper curve; 5 nm Ag + 200 nm ZnPc) compared with a conventional solar cell without clusters (lower curve; 200 nm ZnPc). The conventional solar cell without clusters exhibited a local absorption minimum in the wavelength range from 410 - 520 nm. The solar cell comprising the silver clusters according to the invention exhibited a local absorption maximum within this wavelength range. Consequently, the absorption of light is considerably increased by the clusters.

The absolute values, both here and in the other Figures, are not a measure of said increase, since measurements were made on different solar cells which were merely of the same type. Two solar cells of the same type always exhibit efficiencies which are different from each other. Therefore, it is only the qualitative changes in the course of the curves which are a measure of the improvement

achieved.

The associated photocurrent  $I$  of the conventional,  
clusterless solar cell as a function of wavelength  $\lambda$  is  
5 illustrated in Figure 2. The photocurrent analogously  
exhibits a minimum in the range from 420 - 520 nm . Figure  
3 shows the photocurrent of the solar cell comprising the  
silver clusters as a function of wavelength  $\lambda$ . A local  
maximum of the photocurrent in the wavelength region around  
10 450 nm occurs here.

As an estimate, the efficiency is increased by 15 % by the  
introduction of silver clusters of size about 5 nm into the  
active region.

Claims

1. A solar cell, comprising  
  
5 an active region in which charge carriers are generated by incident photons,  
  
means for conducting the charge carriers out of the active region,  
  
10 clusters which are situated in the active region,  
  
characterised in that the clusters exhibit an absorption peak.  
  
15
2. A solar cell according to claim 1,  
wherein the clusters are smaller than 100  $\mu\text{m}$ , and in particular are smaller than 10  $\mu\text{m}$ .
- 20 3. solar cell according to either one of the preceding claims, wherein the clusters consist of at least 100 atoms.
4. A solar cell according to any one of the preceding  
25 claims, wherein the absorption peak of the clusters falls within the wavelength range in which the optical layer of the solar cell without clusters exhibits an absorption minimum or an increase in an absorption edge.  
  
30
5. A solar cell according to any one of the preceding claims, wherein the absorption peak of the clusters falls within the wavelength range of visible light.



Application No: GB 9919446.6  
Claims searched: All

Examiner: COLIN STONE  
Date of search: 23 November 1999

**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:  
UK Cl (Ed.Q): H1K(KEBCA,KEBCS,KEBCX,KEBX,KECA)  
Int Cl (Ed.6): H01L  
Other: ON LINE, W.P.I., EPODOC, JAPIO

**Documents considered to be relevant:**

| Category | Identity of document and relevant passage                                      | Relevant to claims |
|----------|--|--------------------|
| X        | WO 98/04006 A1 UNIVERSITY OF FLORIDA   | 1                  |
| X        | US 4816183 TRUSTEES OF L.S.J.UNIVERSITY (See cols 9,10)                        | 1                  |
| X        | US 4625071 CHRONAR   | 1                  |
| X        | Pat.Abs.of JP., Vol.17, No.22(E-1307), 14/7/93, page 94 and JP4-249375 (SHARP) | 1                  |

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|---|---|---|--|
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